

INTRODUCTION TO SPECIAL ISSUE ON BIODIVERSITY¹

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The study of biodiversity is fundamental to our understanding of life on Earth and to confronting some of the problems caused by our own species. Further, we increasingly count on biodiversity for a wide variety of ecosystem functions and services amid a gauntlet of anthropogenic changes, including exploding human population levels; global climate change; the spread of invasive species, pests, and pathogens; and overharvesting (Millennium Ecosystem Assessment, 2005). In fact, biodiversity is diminishing at a rate even faster than the last mass extinction at the end of the Cretaceous Period, 65 million years ago, with possibly two-thirds of existing terrestrial species likely to become extinct by the end of this century—the vast majority of them unknown to science at the time they disappear (Millennium Ecosystem Assessment, 2005).

The term biodiversity, coined after the National Academy of Sciences/Smithsonian Institution symposium in 1986 (Wilson, 1988), evokes a great number of perspectives among the general populace and academic sectors. To most laypeople and in colloquial terms, biodiversity implies some indication of the numbers and types of species, genes, and/or species functions. Tropical areas are generally taken to be more biodiverse than temperate and arctic regions; national parks and other protected areas strive to preserve areas of high or unique biodiversity; zoos and botanical gardens make the concept of biodiversity accessible to and appreciated by millions of visitors on a daily basis.

The academic study of biodiversity can be roughly divided into four categories, each of which is essential to our understanding, and ultimately, the preservation, of this essential feature of life.

(1) Taxonomy and systematics. The categorization and description of species, how they are related to one another, and how they are distributed across the globe are essential components of biodiversity studies. Fewer scientists are being trained in this area, however, and funding and other opportunities are somewhat limited. Fortunately, museums and botanical gardens continue to provide leadership in this venue, although training opportunities for students are somewhat limited. Other programs, including the National Science Foundation's Tree of Life program, provide incentives and opportunities to move this area forward.

(2) Evolutionary biology and biogeography. Charles Darwin and Alfred Russel Wallace, among other early evolutionary biologists, showed how the powerful study of biogeographic pat-

terns of species biodiversity, as well as patterns of species traits and distributions, within and among taxonomic groups can shed light onto important evolutionary processes. This area of study remains a mainstay of evolutionary studies, including macroevolutionary and phylogeographic approaches, and has been greatly enhanced in the recent past by the advent of powerful molecular and statistical approaches (e.g., Wiens and Donoghue, 2004).

(3) Ecology. The study of contemporary patterns—as well as recent past (paleoecology) and future (climate change) patterns—of the distribution, biodiversity, and abundance of organisms has become a major area of biodiversity studies. In particular, following the influential works by Hutchinson (e.g., “Why are there so many kinds of animals?” [1959]), MacArthur (e.g., the equilibrium theory of island biogeography; MacArthur and Wilson [1967]), and others, ecologists strive to understand patterns of biodiversity as it is distributed across the globe, as well as the environmental and spatial processes leading to those patterns. Recently, ecological studies have incorporated evolutionary processes into their understanding of these patterns (e.g., Webb et al. [2002]), providing an important avenue for connections among these fields.

(4) Conservation/restoration. As the human footprint continues to spread across all parts of the planet, many biodiversity studies have shifted focus to more applied realms to ask not just how biodiversity is distributed, but how it is changing, and what we can do to minimize or mitigate these changes. Recently, the field has shifted from one of preservation to one of active restoration and conservation amid multiple uses (e.g., Rosenzweig [2003]). With continued habitat destruction and ongoing global change, humans are undeniably a prominent part of every ecosystem on the planet. As such, human activities, behavior, and economy must be explicitly incorporated into the equation to be able to achieve a more sustainable future.

Although each of these areas represents distinct and somewhat independent scientific endeavors, we hope it is clear that the processes within each area are strongly connected. Evolutionary studies need good taxonomy. Ecological studies need good understanding of the evolutionary relationships among species. Conservation studies need good taxonomy, good evolutionary understanding, and good ecology.

It is far beyond the scope of any individual set of contributions to be able to address all aspects of the study of biodiversity. Recent volumes abound on the study of these different aspects of biodiversity study. Instead, we chose to commission some of the best and brightest biodiversity scientists from each of these areas to provide papers representing the state of the art of their respective subfields. These papers integrate standard review and synthesis, new analyses, and future directions.

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The volume starts with the contribution by Graham (2011), who uses geological and paleontological evidence from the Cretaceous to set the stage for the evolutionary and ecological relationships of species within modern-day ecosystems. Next, a series of papers describe the emergence and evolutionary diversification of several groups of land plants. Shaw et al. (2011) provide an overview of some of the insights that can be gained into the early evolution of land plants by careful studies of “bryophytes” (mosses, liverworts, and hornworts), in particular, by incorporating molecular studies of gene expression at different parts of the life cycle. Endress (2011) explores related features of evolutionary diversification in the angiosperms, with floral diversification as a primary focus. Preston et al. (2011) take an “evo-devo” approach that highlights the role of genetic pleiotropy in the development and diversification of different plant modules. Smith et al. (2011) explore the factors that might influence rates of evolutionary diversification among the angiosperm groups by contrasting more traditional studies of phylogenies with a “megaphylogeny” approach that can be used with the advent of large numbers of genetic sequences available globally.

Next, a series of papers explore the limits to our knowledge of biodiversity using modern molecular tools. Steele and Pires (2011) overview the utility of whole-genome survey sequencing for species identification, taxonomic resolution, and understanding evolutionary relationships among species. Blackwell (2011) identifies fungi as a very poorly understood group of species that are extremely important for global processes (e.g., decomposition, disease), and points toward using molecular methods to continue to understand and resolve relationships among this group. Finally, Fierer and Lennon (2011) explore microbial diversity, and among other things, ask whether their high biodiversity is unique within the tree of life or rather simply scales as expected with their small size (and thus high numbers).

The next group of papers combines evolutionary and ecological studies to explore large-scale patterns of biodiversity. Price and Wagner (2011) explore the importance of phylogenetic information and the role of speciation in understanding patterns of the species–area relationship in Pacific Island archipelagos. Vamosi and Vamosi (2011) further explore the effects of area on diversification and key innovations among the angiosperms to understand patterns of biodiversity at global spatial scales. Finally, Swenson (2011) reviews and synthesizes the role of evolutionary processes in creating patterns of biodiversity at the taxonomic, functional, and phylogenetic level.

Moving on to studies on more contemporary (and future) time scales, McGill (2011) starts with a broad synthesis that seeks to simplify (through minimizing) the number of patterns that macroecologists measure as aspects of biodiversity. Gonzalez et al. (2011) show how habitat fragmentation not only reduces the biodiversity of species (through the species–area relationship), but also alters the interactions among other species within the network. Continuing on the theme of global changes, Sylvain and Wall (2011) and Burkle and Alarcón (2011) explore how plant–soil and plant–pollinator interactions, respectively, play a role in the maintenance of biodiversity, and how they will be altered with global change. Powell et al. (2011) review the influence of invasive species on biodiversity and synthesize seemingly disparate results by hypothesizing a scale-dependence in their negative influence on native biodiversity. In the light of these anthropogenic impacts, Brudvig (2011)

reviews the state-of-the-art studies on biodiversity restoration following habitat degradation. Taking a more holistic framework, Franklin et al. (2011) integrate ecological and socio-economic perspectives in the development of ecological reserves that preserve biodiversity and consider the complexity of the human dimension. Finally, Cardinale et al. (2011), using powerful meta-analytic tools, emphasize the importance of biodiversity for the functioning of (and services provided by) ecosystems.

Overall, we hope the reader will agree that the papers in this volume present a fascinating, contemporary sample of the ways in which biodiversity is being studied; from evolutionary to ecological, from micro- to macroscales, from molecules to ecosystems, and from basic to very applied. The cross section of studies includes traditional and meta-analytic reviews, novel theories and statistical analyses, time-tested approaches, and new ideas for future studies. Additionally, we are quite proud to have contributions from perennial, as well as up-and-coming, leaders in biodiversity studies. We expect that many of the papers in this volume will be highly cited and influential as the field moves forward. Although certainly not exhaustive of the field of biodiversity studies, we hope the readers will agree that this collection of papers represents the cutting edge from many different angles, and a darn good read!

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